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AMMUNITION DEVELOPMENT FOR 8IN. MAJOR CALIBER LIGHTWEIGHT GUN.(U)

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NAVAL POSTGRADUATE SCHOOL

Monterey, California

AMMUNITION DEVELOPMENT FOR 8"

MAJOR CALIBER LIGHTWEIGHT GUN

William C. Giauque

Melvin B. Kline

5 April 1977

Approved for public release; distribution unlimited.

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A family of ammunition is currently under development for the 8" major caliber lightweight gun (MCLWG) system. In this report the major alternatives for the propelling charge portion of the ammunition are examined. There are three relatively independent subassemblies in the propelling charge, namely the case, the primer, and the propelling charge itself. Cases can be fabricated of drawn steel, spiral wrapped steel, or other materials, the most

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promising of which is fiberglass. For primers the major options are to rework an existing inventory, to redesign the primers using the traditional technology, or to redesign the primer using more advanced technology. Propelling charge options address the chemical composition (NACO or M1A1) and physical characteristics (grain size). These alternatives are compared using the ideas of multidimensional utility analysis. In this analysis a first "rough" cut was sufficient to enable the project manager to decide among the alternatives.

ABSTRACT

A family of ammunition is currently under development for the 8" major caliber lightweight gun (MCLWG) system. In this report the major alternatives for the propelling charge portion of the ammunition are examined. There are three relatively independent subassemblies in the propelling charge, namely the case, the primer, and the propelling charge itself. Cases can be fabricated of drawn brass, drawn steel, spiral wrapped steel, or other materials, the most promising of which is fiberglass. For primers the major options are to rework an existing inventory, to redesign the primers using the traditional technology, or to redesign the primer using more advanced technology. Propelling charge options address the chemical composition (NACO or M1A1) and physical characteristics (grain size). These alternatives are compared using the ideas of multidimensional utility analysis. In this analysis a first "rough" cut was sufficient to enable the project manager to decide among the alternatives.

AMMUNITION DEVELOPMENT FOR 8"
MAJOR CALIBER LIGHTWEIGHT GUN

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I. INTRODUCTION

A. Origin and Background of the Project

In June 1976 a Naval Postgraduate School research project titled 8" Ammunition Development Study was initiated by the Commander, Naval Sea Systems Command. The research was to focus on various studies with regard to ammunition development for the 8" major caliber lightweight gun (MCLWG). The methodology developed in NPS Technical Report NPS 55Kx75121 (Ref. 1), in particular, multidimensional utility analysis, was to be applied to various ammunition development issues and trade-offs.

As the initial task within this project, the NPS team was asked to evaluate specific suggestions made by Naval Ordnance Station-Indian Head regarding casing, primer, and propellant options. The task was to focus specifically upon the alternatives specified by Indian Head, and was to (1) develop descriptions of each alternative, (2) establish evaluation criteria, (3) rank the alternatives, either singly or in combination as appropriate, along each criterion, and (4) use the multidimensional utility analysis described in Ref. 1 to make optimal choices among the alternatives. This report documents the achievement of these goals.

Two field trips were made to gather data for the study. On 11 - 12 August 1976, the following personnel at Indian Head were interviewed:

Bill Carpentier
John Ratermanis
Craig Smith
Al Horst, and
Steve Mitchell.

Mr. Carpentier's major function is management, Mr. Ratermanis' is working with propellant case fabrication, and the others are engaged in studies of interior ballistics, particularly as related to primer design and propellant composition, fabrication, and loading methods. During the period 13-17 September 1976, the following additional persons were interviewed (their areas of expertise are also noted):

from Naval Surface Weapons Center, Dahlgren, Virginia--

Tom Tschirn (cases, primers, and propellants)

Jim O'Brasky (cases, primers, and propellants), and

Jessie East (primers and propellants);

from Ballistic Research Laboratory, Aberdeen, MD--

Ingo May (primers and propellants);

from Picatinny Arsenal, New Jersey--

Sid Bernstein (primers, propellants, some cases),

Ed Wurzel (primers, propellants, some cases), and

Tony Bendell (primers, propellants, some cases);

from Frankford Arsenal, Philadelphia, Pa.--

Paul Christian (cases), and

Don Donnelly (cases).

Cooperation from all persons interviewed was excellent in terms of both willingness to give their time for the interviews and in frankness and openness. Their assistance is gratefully acknowledged.

B. Approach

In choosing among design alternatives one must typically make trade-offs among many, often competing, criteria. It is possible to systematize one's thinking about trade-offs, including trade-offs

under uncertainty, by making use of multidimensional utility analysis. In essence, this methodology allows one to 1) specify evaluation criteria for the problem at hand, 2) rank each alternative along each of the criteria, 3) assess, in precise unmistakable form, the trade-offs to be made among the criteria, and 4) use these assessments to choose among the alternatives. Reference 2 presents the theory behind this methodology in more detail. A dialogue illustrating the assessment procedure is included in Ref. 1.

In practice the methodology is applied in iterative manner. That is, the alternatives are first defined and evaluated along the evaluation criteria in a relatively crude manner. Very simple arguments can then usually be used to eliminate at least some of the alternatives. The remaining possibilities are then defined somewhat more precisely, more elaborate evaluations used to eliminate some of these, and so on. In this report the first round of evaluation and elimination for the MCLWG ammunition program is discussed. The project manager indicated that this was sufficient to enable him to decide among the alternatives. It would have been a straight forward matter, however, to perform additional analysis cycles should that have proved necessary.

II. DESIGN ALTERNATIVES

The propelling charge assembly for the MCLWG consists of three relatively independent subassemblies, the case, the primer, and the propelling charge itself. A number of options exist in each of these three areas, which are discussed in turn.

A. Case Design

There are four major design options for case design: drawn brass, drawn steel, spiral-wrapped steel, and other.

1. Drawn Brass

The existing inventory of cases is fabricated of drawn brass, the technology is well understood, and the problems are well defined. There is no question about the feasibility of using this technology, but some problems with respect to application to MCLGS have been noted. The gun design is such that the breech assembly is relatively loose, thus the hardness of the existing cases is critical--if too soft, the case extrudes into parts of the breech; if too hard, the case will fracture. Neither problem leads to catistrophic failure of the gun, but they can cause problems with sticking cases and accelerated gun wear. It is inherently difficult to control hardness of the case with any degree of precision; should a major buy in the drawn brass technology be anticipated, possible "fixes" would be either to redesign and strengthen the breech assembly of the gun, or to make the side walls of the case thicker.

Other factors to consider in drawn brass technology are:

- brass is a critical and expensive material, and supply in future years is uncertain;
- the manufacturing process requires a very high fixed cost in tools and dies, and probably only a single source of supply will be available.

On the other hand, brass cases probably would not have to be certified, unless major design changes were required to overcome the hardness problems.

2. Drawn Steel

Drawn steel cases would overcome the problems of fracture and sticking experienced with drawn brass. Steel is a stronger material and possesses enough elasticity to function successfully even in a loose gun. Further, steel is not as expensive as brass, and at least in some grades, is much more readily available. The major problems with drawn steel concern the manufacturing process. Drawn steel cases have been manufactured in 5" and smaller sizes, and the difficulty of manufacture depends a good deal on the depth of the draw. Thus although a deep enough draw to make an 8" casing appears to be possible, given enough development time and money, it is uncertain what the final manufacturing cost would be. The grade of steel used is also likely to be expensive, further increasing the manufacturing costs. Finally, only one manufacturer is currently equipped to manufacture drawn cases, and the expense of the production equipment probably precludes competition from the field. Thus there would probably be a single source of supply, and even here there would

be a major investment in tools and dies. Drawn steel cases would also have to undergo a certification process before being approved for general use.

3. Spiral-Wrapped Steel

Spiral-wrapped steel cases offer a number of advantages:

- experience in 5" and smaller sizes shows that spiral-wrapped cases have the strength and elasticity to perform successfully even in loose guns;
- non-critical grades of steel could be used in case manufacture, indicating relatively low cost and high availability of casing material; and
- the manufacturing process is largely carried out on general purpose, relatively common equipment, indicating that a number of sources of supply potentially exist.

These advantages led Army Ordnance to favor spiral-wrapped steel cases whenever they are certified. In 105 mm tank rounds, for example, cases are available in drawn brass, drawn steel, and spiral-wrapped steel. Relative costs are on the order of $20 (and highly variable), $16 to $17, and $12, respectively. Further, spiral-wrapped steel offers even greater cost advantages in the future, due to multiple sources, and has greater inherent strength than the other materials, opening up the possibility of working at greater pressures.

There are some uncertainties concerning the scaling up of the technologies used in smaller cases to the 8" size. Problem areas exist in maintaining the integrity of the wall-base assembly

during firing and in avoiding crimping of material in strongly necked cases. Both Indian Head and the U.S. Army Frankford Arsenal feel that the base integrity problem can be overcome relatively easily. Each has used somewhat different approaches in the past, indicating that there are probably a number of ways to solve the problem. In the MCLWG crimping at the neck of the case would not be a problem, as the design is not strongly necked.

A spiral-wrapped steel design, like any new design, would have to be certified for use in the fleet.

4. Other

The major other possibility for case manufacture is fiberglass. NSWC, Dahlgren is developing cases for a new family of 8" projectiles for shore-based artillery, and are well into the development of fiberglass cases. The development schedule calls for extensive firing with the new material by August of 1977. The head of the development team claims excellent performance and low cost for this technology, but some outside experts doubt the cost data. In any case the technology has not yet been proven in the field nor have the cost estimates been verified in actual production; thus some uncertainty exists in these areas. These should be resolved within the next year or two.

5. Choice

During the discussions with persons involved in case design, a number of evaluation criteria emerged. The first major area concerned how well the weapon performed in the field. In particular, there was a good deal of concern about possible misfires, in-board detonation of the payload, and cases that stick

in the breach after firing. Some of these are inherently very dangerous to the platform and personnel, while all are potentially dangerous (a sticking case, for example, while posing no immediate hazard in and of itself, puts the weapon out of commission until it is freed, a dangerous condition in combat). Two subcriteria in this area are system performance, that is the expected accuracy, rate of fire, etc. of the weapon, and system reliability, that is percentage of time the system operates within normal limits, as well as the frequency and type of deviations from normality. A second evaluation area concerns costs and material factors. Some of the alternatives involve high fixed costs of manufacture (investment in machines and dies) while others don't. Variable manufacturing costs are also expected to differ. Material availability is a critical factor with brass cases, and to a lesser extent with drawn steel, and thus is a significant evaluation criterion. The possibilities of multiple sources of supply were frequently discussed as an important consideration. The final criteria involved development risks and costs. Risks vary from alternative to alternative, as do development times. One possible advantage to brass cases is the possible lack of certification requirements; thus certification is also included.

Table I summarizes the alternatives outlined above as roughly evaluated along each criterion. Major observations at this point are:

1) Sprial-wrapped steel dominates drawn steel (i.e. is as good or better along each criterion); thus drawn steel can be eliminated.
2) Sprial-wrapped steel dominates fiberglass, but not very strongly. The possibility of "piggybacking" on the fiberglass program, which is continuing

independently of the MCLWG Ammunition Project, could affect our eventual procurement decision, particularly if we can afford to wait until advanced development is completed (by FY 1978).

3) The major trade-off is between drawn brass and spiral-wrapped steel. The spiral-wrapped technology appears, at the moment, to be cheaper and to show more potential for system growth (e.g. higher psi). To make the spiral wrapped technology work, however, we would have to invest development time and money at the front end. If very small buys are anticipated, it might be worthwhile staying with the drawn brass technology.

4) Critical questions, then, are:
   - how large a buy do we eventually anticipate; and
   - can we afford to wait for other programs to do much of the development work (e.g. in the fiberglass cases), and are the other programs working areas that are promising for the MCLWG?

TABLE I.

Criteria for Choice of Case Technology

Criterion	Drawn Brass	Drawn Steel	Spiral-Wrapped Steel	Fiberglass
System Performance	OK	OK	OK	OK (?)
System Reliability	Possible sticking, fracture	OK(?)	Tests show no problems	OK (?)
System Cost				
- fixed manufacturing	High	Very high	Low	Low
- variable manufacturing	High	High	Low	Low (?)
- material availability	Scarce and very costly	Available but costly	Available and cheap	Available and cheap
- source of supply	Single	Single	Multiple	Multiple
Development Considerations				
- risk				
= technological	None	Moderate	None	None
= engineering	Low	Moderate	Low	Low
- time to develop	Short	Long	Moderate	Moderate
- need to certify	No	Yes	Yes	Yes

B. Primer Design

The three major lines of development for primers are to rework the current inventory of Mk-37 primers, redesign the primers using the old technology, and to redesign the primers using newer technology.

1. Rework Mk-37 Inventory

The Mk-37 primers suffer from inherent design problems and poor manufacturing quality. All Mk-37 primers used must be remanufactured at an estimated cost of $25 to $30 each (this cost, based on hand rework, may be reduced during larger scale rework). Aside from the manufacturing problems, the design is such that the interior ballistics are very poor, leading to poor reproducibility, weapon reliability, and accuracy, and contributing to possible gun malfunctions.

2. Redesign Using Old Technology

A number of fairly minor design changes can be made while retaining the basic black powder technology of the Mk-37 primer. These changes involve simplifying the design of the ignition train, changing the spacing of vent holes on the primer tube, and similar changes to reduce manufacturing costs and reliability problems and to improve the interior ballistics. As these concepts are well proven and tested in other weapons, technical risks are nonexistent and engineering risks are very low. The degree of improvement in ignition characteristics is uncertain, but at least some improvement is assured. Eventual costs are also uncertain, but appear to be at most about $15 per primer, in 1976 prices.

3. Redesign Using New Technology

A number of possibilities exist for completely redesigning

the primer. Black powder primers are inherently slow burning, so slow that in the present design the ignition wave in the propellant bed overtakes the ignition front in the primer, rendering all but the first eight inches or so of the primer useless. This results in uneven ignition which leads to severe pressure waves. Redesign would help somewhat, for example, by spacing the first vent holes in the primer tube further from the base, but even then ignition would take place essentially in the middle of the charge. This is much better than at present, but is still far from the ideal, which is simultaneous ignition throughout the length of the primer. Materials are now available which propagate a flame fast enough to closely approach the ideal. There seems to be enough theoretical and experimental work by diverse groups to leave no doubt about the value of the rapid ignition concept in improving interior ballistics. This in turn leads to an entire array of advantages: much better weapon accuracy; less strigent demands on payload packaging; better reproducibility in weapon performance; and fewer catastrophic weapon failures. Some of these factors can be roughly quantified. In the 5"/54, with a muzzle velocity of 20-22 ft/sec., low order pressure waves have been observed to lead to a variation of 5-10 ft/sec. in muzzle velocity. High order waves, in addition to greater variations, also lead to payload fractures and failures. Failures can be virtually eliminated by a better interior environment, and range error can be improved by lowering muzzle velocity variation. It was claimed that NSWC-Dahlgren has demonstrated reductions of muzzle velocity variation from 12 ft/sec. down to 3 ft/sec. Also in the 5"/54 pressurization rates vary from 10 to

50 kpsi/sec. Better primers lower rates to as low as 5 kpsi/sec. while completely eliminating extremely high rates; thus both the average value and variability of pressurization rates can be reduced. Total energy imparted to the projectile doesn't decrease as a result of these changes. Not a single authority on primer technology interviewed in this research cast doubt on the existence of these advantages. Disagreement came only in discussing which new technology is best. Three specific ideas were discussed in this research. These are summarized below, but it should also be kept in mind that a number of other possibilities exist.

a. <u>Black Powder Plus Detonation Cord</u>

This idea benefits from the experience gained from working with black powder over the last several years while gaining many of the advantages of rapid ignition. Black powder has been used for years in primers. It works if handled properly, and is reliable in the sense that it successfully ignites the charge nearly all of the time. It is also relatively cheap, and although the cost of the ignition material is a relatively small part of the cost of the propelling charge, cost factors should carry some weight. On the other hand, black powder possesses a number of disadvantages: it is dangerous to manufacture; it is hygroscopic and must be handled and packaged carefully; and sources of supply are limited. Burning rates and gas and particle generation rates are not consistent, and the slow burn rate of black powder means that the primer continues to dump gas and particles into the propellant for an appreciable length of time, even if the primer is ignited over its entire length through the detonation cord. This again leads to problems in reproducibility of the behavior of the propelling charge.

b. Hivelite Primers

Hivelite is a rapid ignition material which is apparently very successful in igniting the propellant in a smooth, reproducible manner. It is, however, a proprietary, patented material, which implies that it would be available from only one source. The manufacturer is willing to work out plans for alternate manufacture in case of work stoppages, but even then the single source would be of some concern.

c. Benite Primers

Benite consists of black powder in a nitrocellulose matrix which is extruded in long tubes. The geometric form of the material allows for rapid propagation of ignition gasses throughout the primer bed, leading to rapid ignition characteristics. The Army has had a good deal of experience with this material; thus development risks would be relatively low. This material presumably shares many of the advantages and disadvantages of other black powder primers.

4. Choice

In essence, one can choose to use the existing inventory which has known operating characteristics and yields poor results, can undertake a low-scale development effort to correct the most glaring operational and manufacturing deficiencies of the existing design with some improvement in operating characteristics likely, or can embark on a complete redesign. The last course of action certainly shows promise of significant operational improvements, and although each specific alternative has its problems, in total the existence of numerous alternatives indicates a high probability

that a satisfactory improvement will be found. A number of development efforts on primers is currently underway, and although some of them have other purposes in mind (e.g. the Army is primarily interested in combustible primers) results of a good deal of this work could be exploited by the 8" Lightweight Gun in a few years.

Major evaluation criteria evolving from the above discussion are interior ballistics, technical and engineering risks, time to develop the new primer, and whether or not certification for Navy-wide use would be required. The alternatives are ranked on these criteria in Table II. No attempt is made there to discuss individual possibilities in new primer design. Rather, the "New Design" alternative is evaluated as a whole.

At this point, the following conclusions can be drawn:

1) Unless time constraints are very severe and the possibility of certification is an overwhelming disadvantage, a redesign using the old technology is better than reworking the existing inventory.

2) The new technology offers a high probability of significant and substantial operating improvement, but at the cost of a substantial development time and budget. There is also a good chance that the improved primers would cost more than the old technology.

Critical questions then are:

- how much are the operating improvements worth (better range accuracy, greater operating reliability and safety, gentler launch environment) both in development and production costs; and how severe are time pressures on primer development; and

TABLE II.

Criteria for Choice of Primer Technology

Criterion	Mk-37 Inventory	Redesign: Old Technology	Redesign: New Technology
Interior Ballistics	Very poor	Poor to fair	Good to excellent
Technical Risk	None	None	Low
Engineering Risk	Low	Low	Medium overall (but high for individual projects)
Development Time	None	Short (one year)	Medium (three to five years)
Material Availability	Single source	Single source	Depends. Some single source, some proprietary, some generally available
Cost per Primer	\$25 to \$30 for rework	Less than \$15 estimated	Unknown, but some of the materials are expensive
Certification Requirements	None	Probable certification requirement	Certification required

- can we afford to wait for other programs to do much of the development work, and is that work likely to be relevant for the MCLWG?

C. Propellant Design

There are two decisions to be made within the propellant area: whether to use the current Navy NACO propellant or to use a similar Army formulation--M1A1, and whether to use 7-PERF or 19-PERF grain size. There are also some possibilities for interior ballistic improvements in changing the manner in which the propellant is packaged in the case; these are also discussed in this section.

1. NACO vs. M1A1 Propellant

Both NACO and M1A1 are cool burning propellants, with M1A1 having perhaps a slightly higher flame temperature. There is disagreement about the existence and magnitude of this difference, but if it does exist it is quite small. They are of virtually identical chemical compositions, but the M1A1 goes through one less manufacturing step, making it inherently somewhat cheaper to make. There are significant economies of scale in the manufacturing process for either propellant. The NACO propellant was running over \$2.00/lb in small buys in the fall of 1976, and only \$1.40/lb in large purchases. The M1A1 was running about \$0.50 less on small buys, and the price on large buys was estimated to be about the same percentage under the NACO price. Shelf life, handling characteristics, etc. are estimated to be identical. Since NACO is a Navy-specific formulation and M1A1 is used extensively by the Army, a switch to M1A1 by the Navy would be a move toward joint procurement, in line with DOD policy. Justification would have to

be given for staying with NACO. Finally, some engineering development may be necessary to optimize M1A1 loadings and to certify it for Navy use.

2. <u>7-PERF vs. 19-PERF Grain Size</u>

Current Navy practice calls for 7-PERF propellant grains. There may be some advantages in interior ballistic qualities by going to the larger 19-PERF grain size. The larger grains have greater inter-grain spaces, enabling ignition gasses to penetrate more readily, thus giving more uniform ignition. Larger grains also have more mass, decreasing the movements of individual grains within the propellant bed. In addition the 19-PERF size yields a more progressive propellant, giving a greater down-tube pressure for the same maximum pressure, thus increasing the kinetic energy transferred to the payload. The value of these improvements, however, may not be very high. There is agreement that if the ignition system is poor, then the larger grain size would give improved interior ballistics, but not nearly of the magnitude an improvement in the primer design would yield. If the primer were well designed, then the improvement from changes in grain size would be insignificant. Also, the increase in kinetic energy transfer is probably worthless if the recoil limits are binding, as is the case with the MCLWG. On the negative side, large grain size may lower the packing density somewhat (although there is some disagreement on this), and reproducibility of the propelling assembly may suffer, both because it is harder to control all the critical dimensions in the 19-PERF size and because fewer grains would be used per case, lowering to some extent the randomizing effect of mixing various batches in each case loading. In addition, some engineering work would be required

to check temperature sensitivity, pressurization characteristics, etc. of the new formulation. Finally, manufacturing costs of the 19-PERF grains may be somewhat higher, given that more complex dies must be used and more dimensions controlled in the extrusion process, but such differences are likely to be small. In summary, the move to 19-PERF size offers some minor advantages, the worth of which depends on primer design and recoil limits of the weapon and at best are relatively small; while some disadvantages, again of relatively small magnitude, also exist.

3. Choice of Propellant Formulation and Grain Size

Criteria for choice of propellant formulation and grain size are presented in Table III, along with the rankings for each alternative along each criterion. The criteria are again those arising from the discussions among those knowledgeable in the field, and are self-explanatory. At this point, the following observations can be made:

Re. NACO vs. M1A1

1) The M1A1 formulation offers the distinct advantages of lower cost and joint procurement, offset by the need for a minor engineering development effort and perhaps slightly higher flame temperature. If these issues are of concern, data could be gathered, especially on the flame temperature issue, and a structured trade-off made.

2) Critical questions, then, are:

- how serious are the issues of flame temperature, development time, and joint procurement, and
- what are the relative weights of these issues and the propellant cost issue?

TABLE III.

Criteria for Choice of Propellant Formulation and Grain Size

PROPELLANT TYPE

Criterion	NACO	M1A1
Cost	$1.40 - $2.00/lb	$1.05 - $1.50/lb
Flame Temp.	slightly lower (?)	slightly higher (?)
Joint procurement	No	Yes
Development time	None	Short

GRAIN SIZE

Criterion	7-PERF	19-PERF
Interior Ballistics	Baseline	Some improvement with poor primers, insignificant with good primers
Kinetic Energy	Baseline	Perhaps slightly more kinetic energy transfer, but may be counteracted by less loading density; may be worthless in any case.
Reproducibility	Baseline	May be slightly worse
Development time	None	Short
Costs	Baseline	Perhaps slightly higher.

Re. 7-PERF vs. 19-PERF

Critical questions are:

- what primer will be used in the new system and how constraining are the recoil limits of the weapon? If improved primers are being developed, there is probably little worth in developing 19-PERF grains at this time, particularly if the recoil limits are strict.

4. Propellant Packaging Improvements

In the course of the research, some suggestions were made on methods of improving propellant packaging. These were not examined in any detail as they are not within the scope of the research, but are mentioned as promising methods, particularly if some sort of propellant or primer modification study is undertaken anyway.

The first suggestion grows from the observation that void spaces between the top of the propellant bed and the payload adversely affect interior ballistics, in that pressure wave formation is enhanced. One method of eliminating those voids caused by variations in the density and amount of propellant loaded is to use a radial spacer around the inside circumference of the case. This apparently would cause no major manufacturing problems, and would substantially improve the launch environment. The degree of improvement would depend on the geometric shape of the payload (finned projectiles, which already have unavoidable voids in the tail area, would benefit more than conventional projectiles) and the interior ballistic characteristics of the propellant-primer assembly (assemblies tending to pressure wave formation would show greater relative benefits).

A second suggestion is to create a void space at the base of the propellant bed. This has been found to discourage pressure wave formation and decrease the amplitudes of waves that do form, both in the presence and absence of voids at the top of the propellant bed. Greater relative improvements would be expected for unstable than stable propellant-primer assemblies, but even in stable assemblies some improvement appears possible.

III. SUMMARY

At this point, the evaluation criteria are defined and each alternative evaluated, although crudely. This has eliminated some possibilities, tentatively eliminated others, and focused attention on a relatively small number of critical questions in order to choose among the remainder. At this point an assessment was made concerning the relative importance of the critical areas, and the project manager was able to decide among the alternatives.

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